2. Methods

Fairfax County uses various methods to collect data for surface water quality monitoring and analyze it for useable results. The monitoring and analysis methods of the county and volunteer organizations are described below in detail.

2.1 History

In the Stream Protection Strategy Baseline Study, a targeted site selection method was employed. The basic goal was to locate sites that (incrementally) drained two to five square miles and were distributed relatively evenly within the county's watersheds. Most sites were located on second and third order streams (determined from 1:24,000 scale USGS topographic maps).

Fairfax County staff collect aquatic insects in Pohick Creek in March 2004. The samples are used to determine the health of the watershed.

It had been the original intent to continue sampling 20 percent of the targeted sites from the baseline study on an annual, rotating basis, so that an assessment of countywide conditions could be performed after five years. This was initiated in 2001 with a resample of 23 of the baseline study sampling locations (Appendix A). The 2001 sampling also included seven new sites to fill in data gaps identified in the baseline study.

In 2004, the county's biological sampling strategy was re-evaluated and long-term goals established. To meet the long-term goals, it was felt that rather than the 20 percent annual resampling of the baseline study monitoring sites on a rotating basis, it would be more meaningful to infer annual countywide conditions and trends from a probability-based sampling procedure. In addition, various volunteer biological monitoring activities were identified as valuable data sources for site-specific trend evaluations (see Section IV and Appendix B).

2.2 Probability-Based Site Selection

Sampling based on probability survey designs are generally acknowledged to be the best way of obtaining statistically defensible estimates of a variable of interest when a full census is impractical or cost prohibitive. The basic disadvantage with targeted sampling approaches is that it is essentially impossible to establish that the sites targeted are representative of the target population of interest. In probability-based sampling, because sites are randomly selected, every possible sampling unit has a non-zero probability of being selected. This eliminates any site selection bias and provides the basis for making statistical inferences about characteristics of the target population being sampled.

Probability sampling can be implemented in a number of ways, including simple random sampling and stratified random sampling. While simple random sampling is straightforward to implement and results can be easily analyzed, it does not incorporate any information about the target population that could potentially provide more precise results, and it does not allow inferences to be made about any sub-populations of interest. Stratified random sampling, which is probably the most common probability sampling technique in aquatic resource surveys, overcomes the disadvantages of simple random sampling. In stratified random sampling, the target population is divided into a number of mutually exclusive subgroups, called strata, based on some characteristic that results in less variability within each subgroup than the overall variability. Each stratum is then sampled by simple random sampling, and the results from different strata may be combined to give more precise results than if the population had not been stratified.

A key task in developing a probability-based sampling methodology is to establish the sampling frame, which refers to the collection of all possible sampling locations. It is also necessary to uniquely identify every sampling location, and incorporate these locations into a randomization scheme to allow probability-based selection of sampling locations. Additionally, for stratified random sampling, the sampling frame must clearly demarcate the different strata.

A high-resolution Digital Elevation Model of the county, created from over 1.1 million spot elevations, was used to create a synthetic stream network at a threshold of 50 acres*. All stream segments were assigned a Strahler stream order. The synthetic stream network was utilized as the basic sampling frame. A stratified random sampling procedure was employed based on Strahler stream order, with samples allocated in a proportional manner according to the total stream length in each stratum (Table 1).

A two-stage procedure was employed to determine sampling locations. Within each stratum, a stream segment was first selected at random. A sampling location was then randomly selected within each segment. The final sampling locations used for the 2004 monitoring campaign for all strata are shown in Figure 2. (for more information see Appendix G)

An example of a first order stream in Occoquan.

Table 1. Number of sampling sites per stream order.

Stream Order	Total length (mi)	Percentage of total (%)	Number of sampling locations
1	526.5	52.9	16
2	221.8	22.3	7
3	144.1	14.5	4
4	85.4	8.6	2
5	17.0	1.7	1

* The 'threshold' refers to the drainage area that must be equaled or exceeded to initiate a starting point of the synthetic stream network.

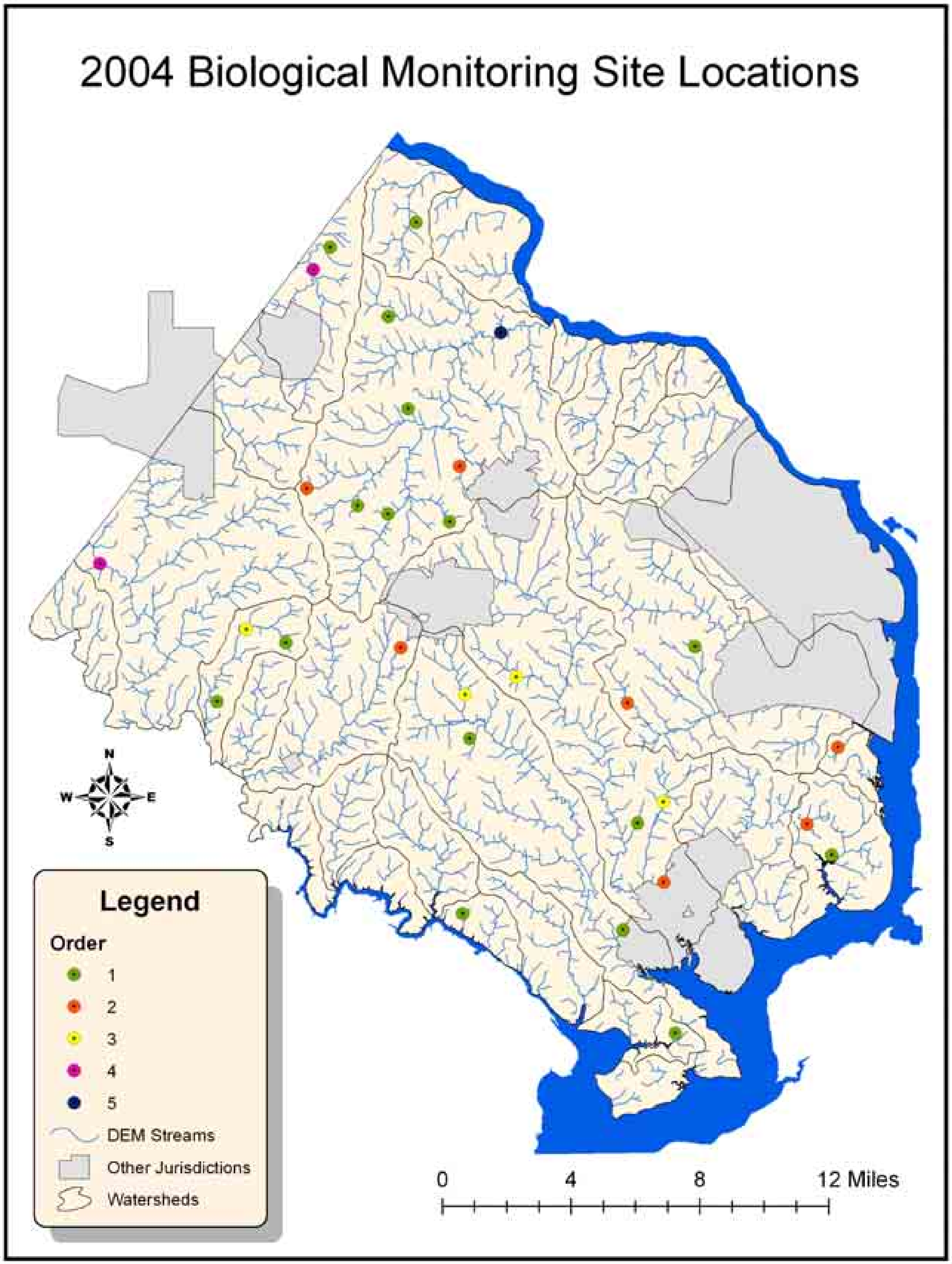

Figure 2: Location of 2004 biological sampling sites.

2.3 Bacteria

Fairfax County conducts bacteria sampling throughout the county to determine the concentration of fecal coliform and *E. coli* in the streams which can be harmful to humans.

The first full year that the Stormwater Planning Division assumed bacteria monitoring activities from the Health Department was 2004. The 80 original sampling sites were sectioned into nine separate zones (Figure 3). Each zone was sampled four times in 2004, for a total of more than 300 bacteria samples.

2.3.1 Procedures

Bacteria sampling involved taking grab samples from the stream to determine the concentration of fecal coliform and *E. coli* in the water. In addition to the assessment of bacteria, sterile bottles were used to collect samples to assess Nitrate (NO_3^-) and Phosphate (PO_4^{-3}) as a secondary test for possible human inputs. Finally, chemical parameters, such as pH, water temperature, dissolved oxygen, and specific conductance were recorded during bacteria sampling using a combination of YSI 85, YSI 556, and Accument Portable pH meters. The sampling techniques, the sample site locations, the parameters sampled for, as well as the chemical data collected for each site was identical to the previous Health Department monitoring program (Appendix D).

Fairfax County staff collecting a bacteria sample in February 2004. Results from the samples indicate that Fairfax County streams are not safe for recreational contact.

2.3.2 Analysis

Beginning in May of 2004, the concentration of *E. coli* in water samples was determined in addition to fecal coliform concentrations. This was in response to the EPA recommendation to use concentrations of *E. coli* and enterococci rather than concentrations of fecal coliform to better determine possible health issues associated with surface waters. Virginia's Department of Environmental Quality has also adopted new *E. coli* standards for water quality.

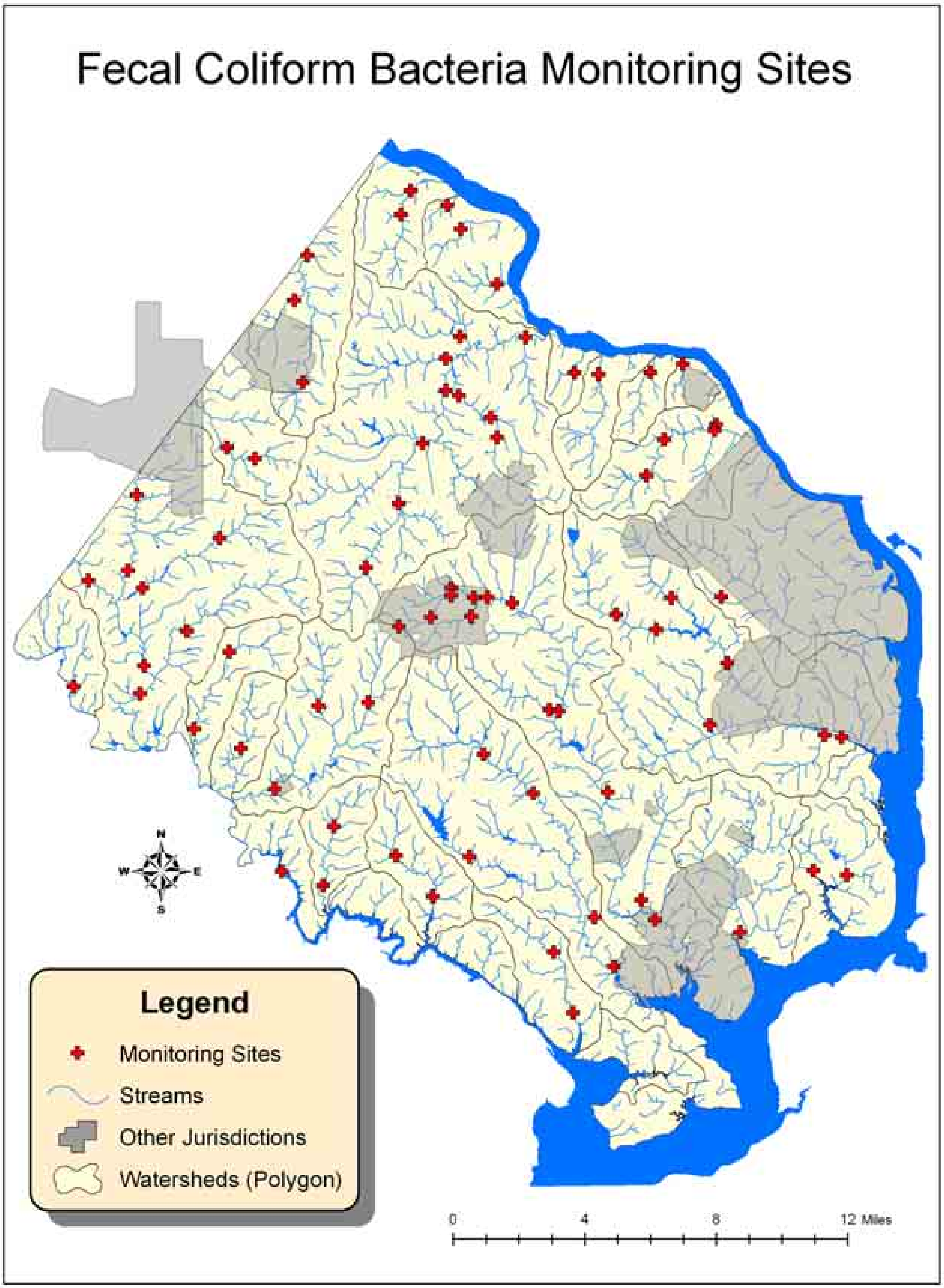

Figure 3: Locations of bacteria monitoring sites.

2.4 Fish

Fish sampling is done by the county because a collection of fish represents the apex of most stream communities. Fish typically are at the top of the food web and are sensitive to both natural and anthropogenic changes within a given system and are, therefore, useful indicators of stream ecosystem health.

Fairfax County staff sampling fish in Pohick Creek in August 2004. Samples are taken to determine stream ecosystem health.

2.4.1 Sampling

Fairfax County conducts fish sampling every summer using the U.S. Environmental Protection Agency's (EPA) Rapid Bioassessment Protocol (RBP) for Use in Wadeable Streams and Rivers (Barbour et al. 1999) to determine stream ecosystem health. Samples were collected in the field using electrofishing equipment that temporarily stuns fish, allowing them to be netted with relative ease. The fish were then identified and released back into the stream. See Appendix C for more detailed information on sampling and laboratory methods.

2.4.2 Analysis

In the baseline study an attempt was made to quantify the health of each of the 30 watersheds using an index based on the fish community data. The data collected at that time was not used to create a Fish Index of Biotic Integrity (F-IBI), similar to index that was developed for the benthic macroinvertebrate data, which is described later in this document. The development of a fish index is an additional useful tool because fish communities are sensitive to different stressors, such as blockages, compared with benthic macroinvertebrates.

Fairfax County staff evaluated an extensive suite of candidate metrics and each metric was evaluated based on trophic characteristics, tolerance, and community structure. The county assessed each metric for its usefulness in developing a fish index. Metrics tested were similar to those tested by Dr. Billy Teels whose work was completed in the Occoquan watershed in 2001. Metrics used by the statewide Maryland Biological Stream Survey (MBSS) were also tested. Metrics were chosen on their ability to correlate with imperviousness, ability to distinguish most disturbed sites from least disturbed sites and frequency of appearance in literature (Table 2).

Fairfax County staff identifying fish species in a sample in August 2004. The number and type of species are used to determine a Fish Index of Biotic Integrity (F-IBI).

There are two physiographic provinces in the county, Coastal Plain and Piedmont. Studies have shown that there is a significant difference in fish communities in the Coastal Plain versus the Piedmont (Smogor 1999, Roth et. al 2005). A small portion of Fairfax County is in the Coastal Plain, but there are few reference areas available in this small portion. The fish index for the Coastal Plain will be based on metrics and scoring criteria used by Roth et al. in Maryland Coastal Plain streams. Metrics used for Piedmont streams are similar to those used by Teels. Metrics for the Piedmont were chosen based on their ability to correlate with imperviousness and ability to distinguish most disturbed sites from least disturbed sites. Scoring criteria was determined using the tri-sectioning method as detailed by Fausch et al. (1984) and Karr (1986) and results are similar to Teels. Further refinement of the metrics and/or scoring criteria could occur in the future as more data is collected, particularly for the Coastal Plain.

Table 2: Metrics chosen for the Piedmont Fish Index of Biotic Integrity.

METRIC	DESCRIPTION
1. Number of Native Species	Number of species in sample that are native to the Potomac Drainage.
2. Number of Darter Species	Number of species in sample that are darters.
3. Percent Tolerant	Percent of individuals in the sample that are classified as being tolerant.
4. Number of Intolerant Species	Number of species in sample that are classified as being intolerant.
5. Percent Omnivores	Percent of individuals whose functional feeding group is omnivores.
6. Percent Benthic Invertivores	Percent of individuals whose primary functional feeding group is benthic invertivores.
7. Percent Carnivores	Percent of individuals whose primary functional feeding group is carnivores.
8. Percent Lithophils	Percent of individuals that spawn on clean gravel.
9. Percent Anomalies	Percent of individuals in the sample that have wounds, diseases, or parasites.

Table 3: Metrics chosen for the Coastal Plain Fish Index of Biotic Integrity.

METRIC	DESCRIPTION
1. Percent Tolerant	Percent of individuals in the sample that are classified as being tolerant.
2. Percent Omnivores and Invertivores	Number of species whose functional feeding group is omnivores and/or invertivores.
3. Percent Non-tolerant Suckers	Percent of individuals in that sample that are suckers not classified as tolerant.
4. Percent Dominance	Percent of sample that is the most abundant species.

Measures of fish community richness typically increase with increasing stream discharge or order, and the values were adjusted accordingly to generate an ultimate rating of: excellent; good; fair; poor; and very poor (Table 4).

Table 4: Classification rating for the Fish Index of Biotic Integrity.

Fish Index Score		RATING
Piedmont	Coastal Plain	
> 34	-	Excellent
30 to 34	>17	Good
25 to 29	14 – 17	Fair
20 to 24	10 - 13	Poor
< 20	< 10	Very Poor

See Appendix C for a more in-depth explanation on the creation and use of the fish index.

2.5 Benthic Macroinvertebrates

Benthic macroinvertebrate samples are collected by county ecologists to help determine the water quality of streams. Benthic macroinvertebrates are important indicators of water quality of their varying tolerances to chemical, nutrient, and sediment pollution in waterbodies. Benthics are also an important link in any aquatic food web by forming the core diet of many stream fishes.

2.5.1 Sampling

The county conducts benthic macroinvertebrate sampling at all sites in late winter to early spring using the 20 jab multi-habitat sampling protocol of the U.S. Environmental Protection Agency's (EPA) Rapid Bioassessment Protocol (RBP) for Use in Wadeable Streams and Rivers (Barbour et al. 1999). The "20 jab" method involves taking 20 separate "jabs" or collections from representative habitat types in the reach including undercut banks, aquatic vegetation, riffles and snags. The benthics that are collected are brought back a county lab where they are subsampled which means that 200 individual benthic macroinvertebrates (plus/minus 20 percent) are picked. The subsample is then identified to the

Fairfax County staff sampling benthic macroinvertebrates in Kane Creek in April 2004. Samples are taken to determine the stream ecosystem health based on an Index of Biotic Integrity (IBI).

genus level where possible with all others categorized at a higher taxonomic level due to time constraints. See Appendix B for more detailed information on sampling and laboratory methods.

2.5.2 Analysis

The data obtained from the identification of the benthic macroinvertebrate samples was then used within a framework of pre-established metrics. Each metric is a numerical valuation reflecting the tolerance or trophic structure variables of the benthic macroinvertebrate community. The metrics are combined into a Benthic Index of Biotic Integrity. A metric set that was developed for use within the Northern Virginia Piedmont areas (Jones 2000, personal communication) was used for sites located within the Piedmont physiographic region of Fairfax County (Table 5). The metrics used in the benthic index for sites in the Coastal Plain region were based on a metric set (Table 6) created by Maxted et al. (1999).

Table 5: Metrics for the Piedmont Benthic Index of Biotic Integrity.

METRIC	DESCRIPTION
1. Taxa Richness	Number of different taxa at a site.
2. EPT Taxa	Number of Mayfly, Stonefly, and Caddisfly taxa at a site.
3. Percent EPT	Percent of Mayfly, Stonefly, and Caddisfly taxa at a site excluding the Net-Spinning Caddisfly (Hydropsychidae).
4. Percent Trichoptera without Hydropsychidae	Percent of sample that are Caddisflies excluding the tolerant Net-Spinning Caddisflies (Hydropsychidae).
5. Percent Coleoptera	Percent of sample that are beetles.
6. Family Biotic Index (FBI)	General tolerance/intolerance of the sample.
7. Percent Dominance	Percent of sample that is the most abundant taxa.
8. Percent Clingers + Percent Plecoptera	Percent of individuals whose habitat type is clingers plus percent of sample that are stoneflies but are not clingers.
9. Percent Shredders	Percent of individuals whose primary functional feeding group is shredders.
10. Percent Predators	Percent of individuals whose primary functional feeding group is predators.

Table 6: Metrics for the Coastal Plain Benthic Index of Biotic Integrity.

METRIC	DESCRIPTION
1. Taxa Richness	Number of different taxa at a site
2. EPT Taxa	Number of Mayfly, Stonefly and Caddisfly taxa at a site
3. Percent Ephemeroptera	Percent of sample that are Mayflies
4. Hilsenhoff Biotic Index (HBI)	General tolerance/intolerance of the sample
5. Percent Clingers	Percent of individuals whose habitat type is clingers.

For each individual metric, sites were scored on a scale of 0 (low correspondence) to 10 (high correspondence) relative to the reference condition. For Piedmont sites, comparisons were made to reference sites sampled in Prince William Forest Park, while Coastal Plain sites where compared to Kane Creek in southeastern Fairfax County based on the use of least impaired sites approach recommended by Karr et al. (1986). Values from each suite of metrics (10 for the Piedmont region and 5 for the Coastal Plain region) were then added together to develop a single benthic index measured on a 0 to 100 scale. In the Coastal Plain, values were doubled to produce a comparable 0 to 100 scale. Based on this value, individual sites were given a qualitative rating within one of the following five categories: excellent; good; fair; poor; and very poor (Table 7).

Table 7: Benthic Index of Biotic Integrity scoring and equivalent rating system.

BENTHIC INDEX SCORE	RATING	DESCRIPTION
80 to 100	Excellent	Equivalent to reference conditions; high biodiversity and balanced community.
60 to 80	Good	Increased number of intolerant species; balanced community
40 to 60	Fair	Marked decrease in intolerant species; shift to an unbalanced community.
20 to 40	Poor	Intolerant species rare or absent, decreased diversity.
0 to 20	Very Poor	Degraded site dominated by a small number of tolerant species.

See Appendix B for a more in-depth explanation on the creation and use of the benthic index.

2.6 Volunteer Monitoring

2.6.1 Audubon Naturalist Society

The Audubon Naturalist Society water quality monitoring program recruits, trains, equips, and organizes volunteers to assess the health of streams throughout the Washington, D.C., region. The program uses a modified version of the EPA's Rapid Bioassessment Protocols (RBP) to perform habitat assessments and benthic macroinvertebrate surveys (see Appendix E). All monitoring equipment is provided. There are six permanent sites within Fairfax County that are covered by 20 to 30 volunteers each year (Figure 5). The data collected by the society volunteers are currently shared with the Department of Environmental Quality, Prince William County, Fairfax County, National Park Service, and Department of Game and Inland Fisheries.

Volunteers assess habitat conditions and macroinvertebrate community composition (usually to family level) at specific points throughout the year (May, July, and September, with an optional winter sample). Macroinvertebrates are collected using a “hand-scrubbing” sampling technique whereby the volunteers pick up rocks from the stream and rub them in a bucket filled with stream water to detach any macroinvertebrates on the rocks. All benthics that are collected using this method are visually identified to the family taxonomic level where possible. Multiple samples are collected from riffle and pool areas.

Monitors gauge overall habitat condition by visually assessing parameters such as substrate composition, embeddedness, turbidity, bank cover and canopy cover. Four other components of the EPA's habitat assessment—channel flow status, bank stability, sediment deposition and riparian zone width—are also scored using a visual assessment. Readings of pH and water temperature are taken concurrently.

2.6.2 Northern Virginia Soil and Water Conservation District

The Northern Virginia Soil and Water Conservation District coordinates a volunteer stream monitoring program first established in 1997 that is open to all individuals interested in water quality issues. Training includes indoor and field workshops and mentoring by experienced monitors. Volunteers commit to monitoring their chosen stream four times a year or assist other monitors at their sites. Sites are located throughout the county and in the City of Fairfax.

Blythe Merritt, Northern Virginia Soil and Water Conservation District and Audubon Naturalist Society volunteer monitor, sorting a sample in Cub Run in December 2003. Volunteer data supplements the county's data. (photo NVSWSD)

The conservation district initially used the Izaak Walton League Save Our Streams (SOS) protocol for biological monitoring. The protocol classified stream condition based on the absence or presence of organisms. In 2001, the conservation district adopted the use of a new, modified Virginia Save Our Streams protocol (Figure 4). The new protocol was the result of graduate research at Virginia Polytechnic Institute and State University. The new method takes both abundance and diversity into account when calculating six metrics and using a multi-metric for the final score (see Appendix E).

Monitors sample riffles by disturbing the stream bottom and collecting dislodged insects with the use of a three foot-square net. At least 200 organisms are collected and identified. Monitors calculate six metrics, and then use a multi-metric approach to score the site as having an acceptable or unacceptable ecological condition. The final score ranges from zero to twelve. Volunteers also conduct chemical analyses of turbidity and nitrate/nitrite and make physical observations. The conservation district provides all monitoring equipment.

Virginia Save Our Streams Macroinvertebrate Tally Sheet

Macroinvertebrates	Tally	Count	Macroinvertebrates	Tally	Count
Worms			Common Netspinner Caddisfly		
Flat Worms			Most Caddisflies		
Leeches			Beetles		
Crayfishes			Midges		
Sowbugs			Black Flies		
Scuds			Most True Flies		
Stoneflies			Gilled Snails		
Mayflies			Lunged Snails		
Dragonflies and Damselflies			Clams		
Hellgrammites, Fishflies, and Alderflies			Other		
			Total number of organisms in the sample		

Illustrations from: Voshell, J. R., Jr. 2001. Guide to the Common Freshwater Invertebrates of North America. MacDonald and Woodward Publishing Co. With permission of the author.

Individual Metrics

Metric	Number		Total number of organisms in the sample		Percent
Mayflies + Stoneflies + Most Caddisflies		Divide by		Multiply by 100	
Common Netspinners		Divide by		Multiply by 100	
Lunged Snails		Divide by		Multiply by 100	
Beetles		Divide by		Multiply by 100	

% Tolerant

Taxon	Number
Worms	
Flatworms	
Leeches	
Sowbugs	
Scuds	
Dragonflies and Damselflies	
Midges	
Black Flies	
Lunged Snails	
Clams	
Total Tolerant	
Total Tolerant divided by the total number of organisms in the sample	
Multiply by 100	

% Non-Insects

Taxon	Number
Worms	
Flatworms	
Leeches	
Crayfish	
Sowbugs	
Scuds	
Gilled Snails	
Lunged Snails	
Clams	
Other non-insects (organisms without 6 jointed legs)	
Total Non-Insects	
Total Non-Insects divided by the total number of organisms in the sample	
Multiply by 100	

Figure 4: Example field data sheets for the Virginia Save Our Streams Protocol.

There are between 40 and 50 sites that are monitored during a typical year, with 35 sites that currently have several years' worth of data (Figure 5).

More than 700 volunteers have participated in collecting data. Certified data is forwarded to Fairfax County, the Department of Environmental Quality, Virginia Save Our Streams, and other interested organizations or individuals.

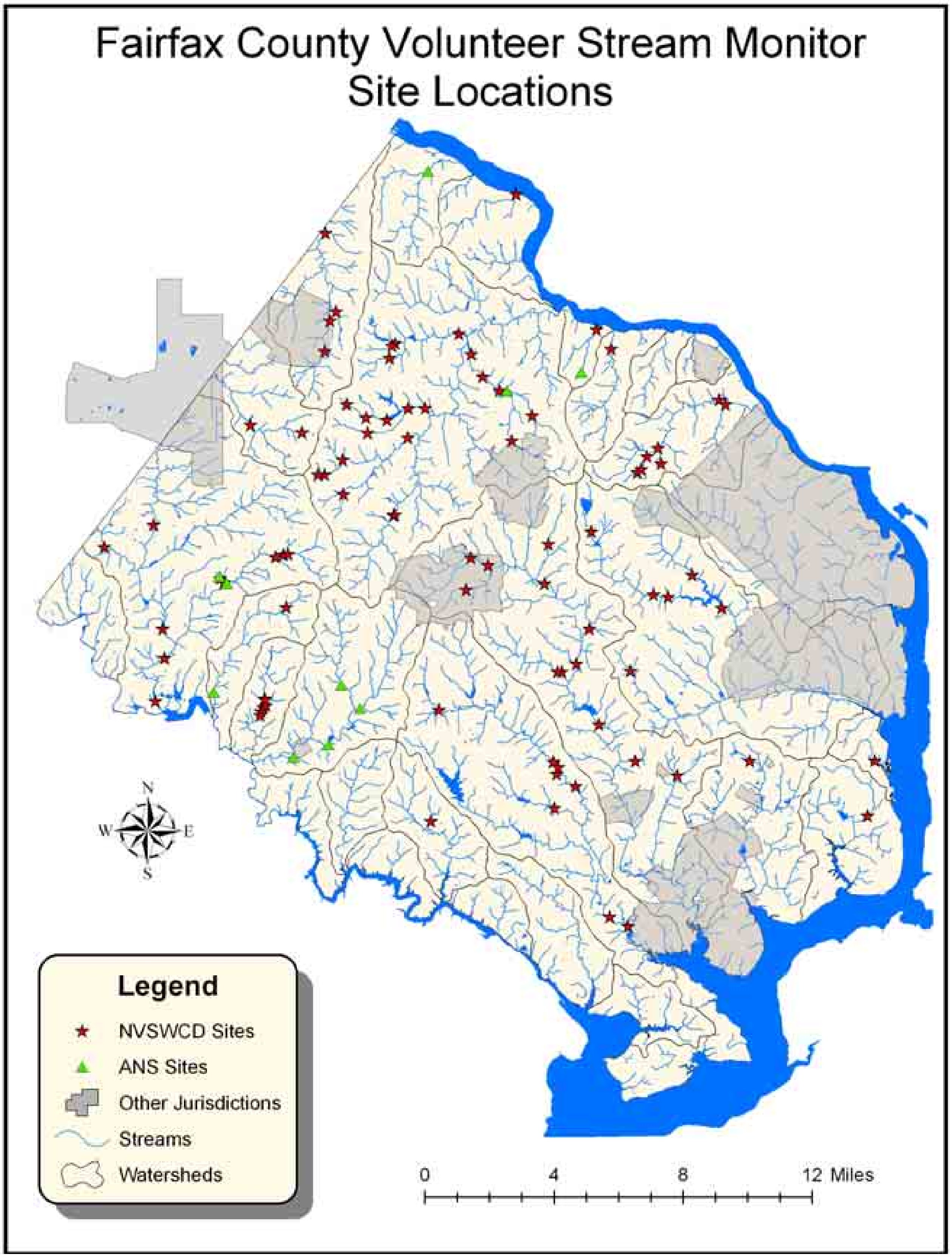

Figure 5: Location of volunteer monitoring site locations.